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Basic Patent (No,Kind,Date): JP 3129606 A2 910603

&lt;No. of Patents: 001&gt;

## PATENT FAMILY:

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AERIAL POWER CABLE (English)

Patent Assignee: HITACHI CABLE

Author (Inventor): SHIMOJIMA KIYOSHI; OSHIMA OKIHIRO; HIDA SHUJI

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KOKAI PATENT APPLICATION NO. HEI 3-129606

**AERIAL POWER CABLE**

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AERIAL POWER CABLE

[*Kakuh sohden'sen*]

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*[There are no amendments to this patent.]*

**Specification**

**1. Title of the invention**

Aerial power cable

**2. Claims of the invention**

(1) An aerial power cable made of FRP (Fiber-Reinforced Plastic) wire produced by binding an organic or inorganic fiber having a high tensile strength such as aramide fiber,

silicone carbide fiber, or carbon fiber as a tension fiber, and providing a synthetic resin with high strength as the binder in a linear-shape; the aerial power cable is characterized by the fact that the single cable or multiple cable is covered with a metallic casing consisting of a metallic tape wrapped around or attached longitudinally.

(2) The aerial power cable described in Claim 1 above in which a perforated tape is used for the metal tape used for the casing.

(3) An aerial power cable in which a carbon fiber or silicon carbide fiber is used as the tension member and bound with an epoxy resin that serves as the parent phase, and coating is further performed with a polyimide resin or wrapping is done with a polyimide film and cabling is carried out for an FRP fiber used as the wire element.

(4) An aerial power cable in which cabling is carried out for an FRP fiber produced by binding carbon fiber or silicon carbide fiber with an epoxy resin that serves as the parent phase, and bonding is carried out in the space between the cabled wire elements with a polyimide resin or the cable is coated with a polyimide resin.

### 3. Detailed description of the invention

#### [Field of industrial application]

The present invention pertains to an aerial power cable and the invention further pertains to an improved aerial power cable having reduced weight of the power cable itself, a significantly improved relaxation of the aerial cable, and a cable which is capable of reducing the height of the steel tower.

[Prior art]

In the past, a steel-cored aluminum cable such as the one shown in Fig. 14 has been used for aerial power cables for transmission of electrical power from the power source.

[p. 2]

In which, 1 are galvanized steel wires that serve as the tension member, and the galvanized steel wires are formed into a cable to produce a steel core and aluminum wire elements 2,2 are formed and serve as the electrical conduction member.

In recent years, the demand for power has been increasing, and attempts are being made to increase the power capacity using the same power lines or to build steel towers as low as possible to reduced the overall cost.

As a means to increase the power transmission capacity of the power line without increasing the outer diameter of the power line or increasing the height of the steel tower,

(1) a method wherein the strength-to-weight ratio (tensile strength/unit weight) is increased so as to keep an adequate tension with a thin power line, and the cross section area of the aluminum wire elements that form the electrical conduction members is increased instead.

(2) a method wherein an amber wire having a coefficient of expansion of the wire 1/10 that of steel wire is used for the core instead of conventional galvanized steel wire to increase the energy capacity of the power line, and when heat is generated as a result of energy and overall thermal expansion of the power line occurs and an amber line having a low coefficient of expansion is used as the tension member, a reduction in the loosening of the aerial line can be achieved.



(3) A method wherein an FRP wire produced by binding an aramide fiber or carbon fiber having a weight approximately  $1/5$  that of steel with a resin having a high strength such as a polyester type resin or an epoxy type resin instead of the above-mentioned galvanized steel wire or amber wire so as to reduced the weight of the wire itself while maintaining the strength of the tension member, and to reduce the degree of loosening of the wire based on the weight itself, have been suggested.

[Problems to be solved by the invention]

Among the above suggestions, power lines wherein an amber line is used as the tension member described in (2) are being used in practice, and it is possible to reduce the coefficient of expansion of the amber wire itself, but the strength remains inadequate compared with steel wire; thus, it has not been possible to use the method suggested in (1) where the thickness of the tension member is reduced and the cross section area of the electrical conduction member is increased. Furthermore, the weight of the amber wire is approximately the same the weight of the conventional galvanized steel wire, and it is necessary to hang the aerial wire uniformly. As for the suggested solution described in (3), it has been said that the strength is greater than steel depending on the type of fiber used, and that it can be applied to the solutions suggested in (1) and (2). However, the heat resistance of the plastic used as a binder for the above-mentioned FRP wire is very low compared with the metal used in suggested methods (1) or (2) above, and ignition may occur at high temperatures. Furthermore, the bend resistance and impact resistance of FRP

wires made of resins such as the above-mentioned polyester type resin or epoxy type resin are poor. Therefore, in the case when a power line having the above-mentioned FRP wire as the tension member have yet to be produced, and it is not possible to use the hoisting drum used for conventional power lines, and it is necessary to increase the diameter of the wheel of the drawing car at the time of line construction, or to increase the radius of the metal wheel suspended from the steel tower so as to avoid sharp bending of the electrical wire.

Also, the heat resistance is inadequate when an epoxy type resin is used, and despite the high heat resistance of the above-mentioned fiber, which is 1200~2500°C, the temperature of the electrical wire in which the FRP is used as the tension member is approximately 150°C, at the most, as a result, the effect of the reduction in the coefficient of expansion of the wire compared to the above-mentioned amber wire cannot be achieved in this case. Furthermore, thermal deterioration is expected with long-term use, which poses a problem when used as the tension member for aerial power cables where long-term reliability is required.

Based on the above background, the objective of the present invention is to produce an aerial power cable having a new type of FRP wire as the tension member, wherein an FRP wire is used as the tension member and production is carried out with a production device, aerial jigs, or aerial parts used for conventional steel core and aluminum element wires.

[p. 3]

[Means to solve the problem]

The present invention is an aerial power cable wherein the single cable or multiple cables are covered with a casing consisting of a metallic tape wrapped around or attached longitudinally in an aerial power cable made of FRP (Fiber-Reinforced Plastic) wires produced by binding organic or inorganic fibers having high tensile strength such as aramide fibers, silicone carbide fibers, or carbon fibers as the tension fiber, and a synthetic resin binder with high strength as a binder in a linear shape.

In the above-mentioned aerial power cable, a perforated tape is used for the metal tape used for the casing, and carbon fibers or silicon carbide fibers are used as the tension member and are bound together with an epoxy resin used as the parent phase, and further coating with a polyimide resin is carried out or wrapping with a polyimide film is performed and cabling is carried out for the FRP fiber used as the wire element; furthermore, cabling is performed for an FRP fiber produced by binding a carbon fiber or silicon carbide fiber with an epoxy resin used as a parent phase, bonding is performed for the space between the cabled wire elements with a polyimide resin or the cable is coated with a polyimide resin.

[Work of the invention]

When a metal casing made of a metal tape is formed around the FRP wire, the above-mentioned metal tape functions as a buffer layer and brittleness of the FRP wire upon bending or under impact can be reduced significantly. At the same time, thermal

deterioration of the resin inside can be effectively prevented and an aluminum cable reinforced with FRP having long-term reliability can be produced.

Furthermore, the effect of the above-mentioned buffer layer can be adequately maintained even when a polyimide resin having a high heat resistance and high strength is used instead of the above-mentioned metal tape.

#### [Application Examples]

In the following, the present invention is explained in further detail with drawings.

Fig. 1 is a cross-section diagram that shows an application example of the aerial power cable of concern in the present invention.

In the figure, 4 are the FRP wires that serve as tension members, 3 are the metal tapes formed around the tension members, and 2 are the aluminum wire elements that surround the above-mentioned tension member.

Fig. 2 shows a specific structural example of an FRP wire used as the tension member as described above, and Fig. 2(a) is the front [side] view and Fig. 2(b) is the cross-section view. In the application example, a metal tape is tightly wrapped around the wire as shown in the figure, and [thereby] metal outer casing 3 is formed around the FRP wire.

Furthermore, Fig. 3 shows a different application example, and Fig. 3(a) is an explanatory front view and Fig. 3(b) is the cross-section view. In the application example, a metal tape is attached longitudinally and the butt ends are not bonded so that opening 3a is formed.

Unlike the case of extrusion coating where the wire is coated entirely with the metal, a partial opening is provided in this case so as to prevent expansion and subsequent rupturing due to gas generated from the resin used as a binder and trapped inside the metal.

Thus, in the case of the present invention, unless the perforated tape described below is used, it is important to avoid completely sealing the FRP wire inside the metal cladding.

Fig. 4 and Fig. 5 each show different application examples, and the FRP wire consisting of the cable itself, and a metal casing made of a metal tape is formed around the cable.

In other words, Fig. 4 shows the case where a metal tape is wrapped around a cable made of FRP wire 4 so as to form a metal casing. Fig. 3(a) is an explanatory front view and Fig. 3(b) is the cross-section view. Item 5 in Fig. 4 is a plastic, and for example, an adhesive such as an epoxy adhesive is coated around the FRP wire at the time of winding the metal tape, and the metal tape is wrapped around the adhesive to form the metal casing, the adhesive is subsequently cured and forms an inclusion plastic.

Fig. 5 is an example wherein a cable is used for the FRP wire, and a metal tape is attached longitudinally and the butt ends of the tape are overlapped. Fig. 5(a) is the explanatory front view and Fig. 5(b) is the cross-section view.

[p. 4]

It is important to simply overlap the edges 3b without bonding them, in this case as well, and the overlapped area allows the gas generated from the FRP wire to escape.

Fig. 6 shows a different application example of metal tape A used as a metal casing, and Fig. 6(a) shows the top view, and Fig. 6(b) shows the cross section view at A-A of Fig. 6(a).

In the application example, openings 6, 6 are provided in the tape used as the metal casing as shown in the figure. When the above-mentioned perforated tape 3A is used, the gas generated from the FRP can be released through the openings, even when the butt ends of the metal casing are sealed by means of fusion, etc.; thus, expansion and rupturing of the metal casing due to trapped gases can be avoided.

In this case, for the tape used for the metal casing of the present invention, an aluminum tape, aluminum alloy tape, steel tape, galvanized steel tape, etc. can be mentioned, and the selection can be made appropriately.

Furthermore, it is necessary to prevent trapping of the gases generated from the FRP wire in the present invention as described above, and when a method wherein the butt ends of the tape are overlapped is used, it is necessary for the overlapping portion to be as narrow as possible, and it is further desirable when a small gap is formed. Even when the width of the overlapping portion is reduced or a gap is formed in the present invention, deterioration in strength does not occur.

When the metal casing is formed around the FRP wire used as the tension member of the aerial power cable, the advantages of the FRP wire itself can be maintained and disadvantages are compensated for by the metal casing, and production of a aerial power cable that is light weight and has high tensile strength is made possible, and long-term reliability can be established.

Fig. 7 shows a different application example of an element wire used for the tension member of the present invention, in which polyimide layer 10 is coated around the FRP wire 4 produced by binding carbon fibers or silicon carbide fibers with an epoxy resin.

The softening point of the polyimide resin is 700°C and deterioration in strength at high temperatures is insignificant, and it is a highly stable material; furthermore, the above-mentioned resin is widely used as a coating material for heat resistant enamel wires.

Thus, when coating of the above-mentioned polyimide is performed, an excellent buffering layer can be produced, though the effect achieved is poor compared to that of the above-mentioned metal tape, the above-mentioned disadvantage of the FRP wire itself can be improved significantly, and [the FRP wire] can be effectively used as a tension member. As for the fiber used in this case, either carbon fiber or silicon carbide fiber is suitable from the standpoint of high strength and weather resistance.

Fig. 8 shows the case in which wrapping of a polyimide film is carried out instead of coating with polyimide to produce polyimide layer 10, and the same good effect can be achieved in this case as well.

Fig. 9 is a cross-section view that shows an application example of the present invention wherein wire elements having polyimide layers 10 on FRP wires are cabled to form a tension member and aluminum wire elements 2, 2 are placed around the cable.

In the application example, each FRP wire is coated with a polyimide layer as described above, but a cable is first formed with the FRP wire and bonding can be performed with a polyimide resin as shown in Fig. 10, and Fig. 10(a) is the front view of the application example, and Fig. 10(b) is the cross-section view.

Fig. 11 shows another different application example, in which tension members 4, 4 are arranged as element wires, and coating is performed for the element wire with a polyimide film as shown so as to produce polyimide layer 10, and Fig. 11(a) is an explanatory drawing and Fig. 11(b) is the cross section view, and the same excellent results can be achieved in this case as well.

[p. 5]

Fig. 12 shows the results of heat resistance test of FRP wire plotted where the structure of the FRP wire is represented by the horizontal axis. As shown in the figure, compared with an FRP wire impregnated with an epoxy resin alone, an increase in the heat resistance can be observed when a polyimide coating is applied. When an FRP wire is produced by impregnating polyimide alone, maximum heat resistance can be achieved, however, polyimide is very expensive, and when the cost factor is taken into consideration, the structures described in the above-mentioned application examples are desirable.

Fig. 13 shows an explanatory drawing of production of a specific example of a wire element member of the present invention, in which fiber yarns 4a are supplied from bobbins 20, epoxy is impregnated in pressurized dip tank 21 and squeezed out to form a filament, drying is done in drying furnace 22, coating of polyimide layer is carried out in the polyimide coating device 23 (the device may be a polyimide tape wrapping device as well), and drying is further performed by drying furnace 24.

In this case, wrapping of new fiber can be performed after dipping in epoxy and drying or polyimide layer formation process can be carried out after wrapping as well.



## [Effect of the invention]

As described above, in the aerial power cable of the present invention, the weight of the power line itself can be reduced and loosening of the aerial power cable can be significantly reduced. Thus, the present invention is very useful since steel towers with reduced height can be used and an adequate energy supply capacity can be attained.

## 4. Brief description of figures

Fig. 1 is a cross-section view that shows an application example of the aerial power cable of concern in the present invention. Fig. 2 shows a specific structural example of the FRP wire used as the tension member described above, and Fig. 2(a) is the front view and Fig. 2(b) is the cross-section view. Furthermore, Fig. 3 shows a different application example, and Fig. 3(a) is the explanatory front view and Fig. 3(b) is the cross-section view. Fig. 4 and Fig. 5 each show different application examples, and in Fig. 4 and Fig. 5, (a) is the explanatory front view and (b) is the cross-section view. Fig. 6 shows a different application example with metal tape A used as a metal casing, and Fig. 6(a) shows the front view, and Fig. 6(b) shows the cross-section view at section A-A of Fig. 6(a). Fig. 7 shows the cross-section view of a different application example of element wire used as a coating layer. Fig. 8 shows the case where a polyimide film is used as a wrapping layer, and Fig. 9 shows a cross-section view of the power line where an FRP wire coated with polyimide is used as the tension member.

Fig. 10(a) is the front view of the FRP cable bonded with polyimide layer, and Fig. 10(b) is the cross-section view. Fig. 11(a) is an explanatory drawing wherein element wires are

arranged and wrapping with a polyimide tape is carried out, and Fig. 11(b) is the cross-section view. Fig. 12 is a chart showing the heat resistance test results, Fig. 13 is a schematic diagram of the production device used for the polyimide coated FRP wire, and Fig. 14 is a cross-section view that shows a conventional steel-cored aluminum cable wire.

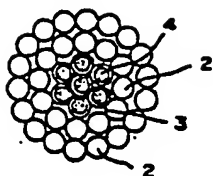
[Explanation of codes]

- 1: Galvanized steel wire
- 2: Aluminum element wire
- 3: Metal casing
- 3A: Metal tape
- 4: FRP wire
- 5: Plastic
- 6: Perforation
- 10: Polyimide layer
- 20: Bobbin
- 21: Pressurized dipping tank
- 22: Drying furnace
- 23: Polyimide coating device
- 24: Drying furnace

Applicant: Hitachi Cable Corp.

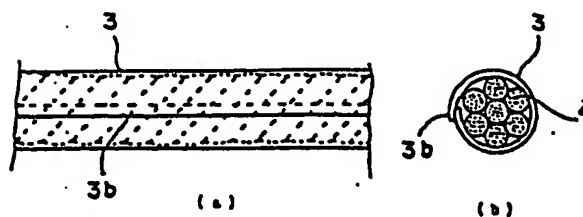
Agent: Fujio Satoh, Patent attorney

[Fig. 1]

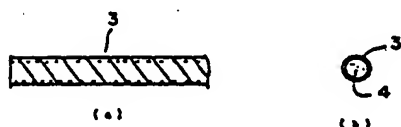


- 2: Aluminum wire element
- 3: Metal casing
- 3A: Metal tape
- 4: FRP wire
- 5: Plastic

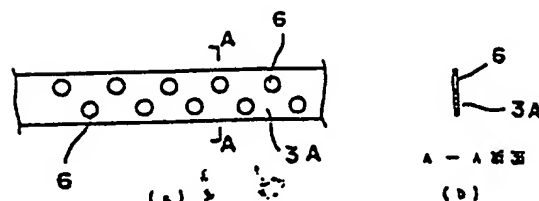
[Fig. 5]



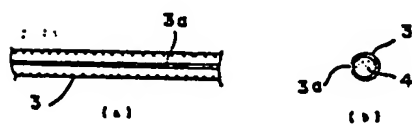
[Fig. 2]



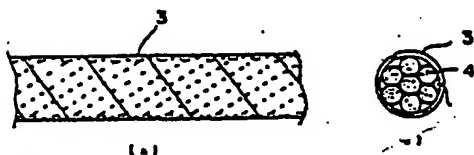
[Fig. 6]



[Fig. 3]



[Fig. 4]

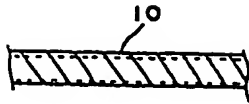


[Fig. 7]

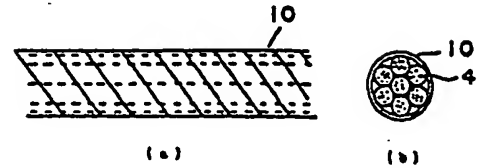


- 3: Metal casing
- 3A: Metal tape
- 3b: Overlapped edges
- 4: FRP wire
- 6: Perforation
- 10: Polyimide layer

[Fig. 8]



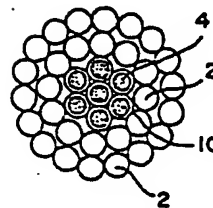
[Fig. 11]



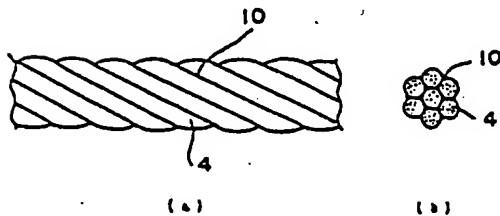
4: FRP wire  
10: Polyimide layer

[Fig. 9]

2: Aluminum wire element  
4: FRP wire  
10: Polyimide layer



[Fig. 10]



[Fig. 12]

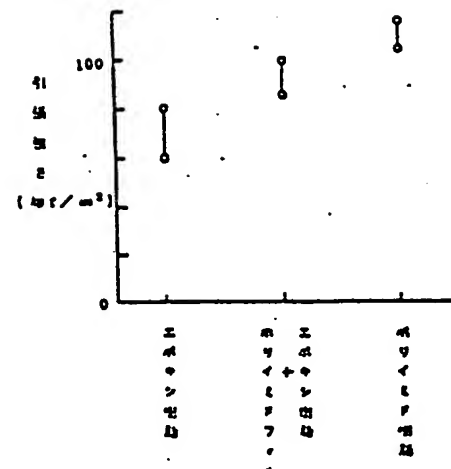
Vertical axis: Tensile strength (kgf/mm<sup>2</sup>)

Horizontal axis:

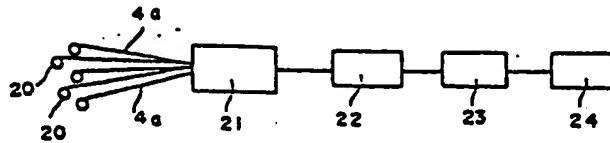
Left side: Epoxy resin  
Center: Polyimide film + epoxy resin  
Right side: Polyimide resin

Diameter of wire element: 0.5 mm  
Carbon fiber: 15  $\mu$ m  
Volume ratio  $v_f=40\%$   
400°C x 1 minute retention

(0.2 cm<sup>2</sup>)



[Fig. 13]



[Fig. 14]

- 1: Galvanized steel wire
- 2: Aluminum element wire
- 4a: Fiber yarn
- 20: Bobbin
- 21: Pressurized dipping tank
- 22: Drying furnace
- 23: Polyimide coating device
- 24: Drying furnace

